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Review

The impact of sleep, stress, and depression on postpartum weight retention: A systematic review☆

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ABSTRACT

Objective: To review the impact of sleep, stress, and/or depression on postpartum weight retention.
Methods: We searched three electronic databases, PubMed, ISI Web of Science, and PsycInfo. Studies were included if they were published between January 1990 and September 2013 in English, measured sleep, stress, and/or depression in the postpartum period, and assessed the association of these factors with postpartum weight retention. Two reviewers reviewed included articles and rated study quality using a modified version of the Downs and Black scale.
Results: Thirteen studies met our pre-defined eligibility criteria, reporting on 9 study samples. Two were cross-sectional studies and eleven were longitudinal studies. The study sample size ranged from 74 to 37,127. All four studies examining short sleep duration and postpartum weight retention reported a positive association. The four studies examining postpartum stress and weight retention reported non-significant associations only. Of 7 studies examining postpartum depression and weight retention, 3 reported non-significant associations, and 4 reported positive associations.
Conclusion: Research investigating the impact of postpartum sleep, stress, depression on weight retention is limited. Future longitudinal studies are needed.

Introduction

The prevalence of overweight and obesity is increasing and has doubled worldwide since 1980 [1]. In 2010, approximately 35% of adult women in the United States were obese [2]. Women of childbearing age are at particularly high risk for significant weight gain during their reproductive years. On average, women retain between 0.5 and 3 kg from their pre-pregnancy weight one year after giving birth; [3] 42% return back to their pre-pregnancy weight [4], 10% retain 5–10 kg, and an additional 3% retain over 10 kg one year postpartum [5]. Women who fail to lose their pregnancy associated weight in the postpartum period are at significant risk of weight gain and midlife obesity in comparison with women who return to their pre-pregnancy weight [6]. Failure to lose weight gained during pregnancy can also lead to increased body mass index for subsequent pregnancies, contributing to an increased risk of maternal and neonatal complications [7]. Based on the above observations, the postpartum period is a window of opportunity to impact the obesity epidemic and favorably influence maternal and child health.

Women experience dramatic alterations in sleep [8–10], life challenges and stress [11,12], and a greater likelihood of experiencing depressive symptoms in the postpartum period [8]. Disordered sleep, stress, and depressive symptoms are associated with weight gain in the general population [13–15]. Average sleep duration of less than 5 hours or over 8 hours have been linked to weight gain and the development of obesity among non-pregnant women [16]. Persistent sleep deprivation results in a variety of physiological changes, including a decrease in plasma leptin levels and an increase in ghrelin levels, which stimulate appetite and contribute to the development of obesity [17]. Persons with high levels of perceived stress, or with multiple stressors, are also at higher risk for developing abdominal obesity and comorbidities [18]. Sleep deprivation, stress, and depression are associated with alterations in plasma cortisol levels [18–20]. Hypercortisolism stimulates the intake of carbohydrates and fat, and reduces energy expenditure [21], which contributes to overall obesity.

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Longer sleep duration and lower stress levels are associated with greater weight loss in weight loss trials [22]. Despite the availability of efficacious postpartum weight loss interventions [23,24], unique challenges exist in the postpartum period, including disruptions in sleep and greater stress and depression. A recent systematic review examining the association between postpartum depression and maternal obesity found mixed results and anti-depressant use was not associated with postpartum weight retention; [25] however, this review did not evaluate sleep duration or stress, which are also potential risk factors for weight retention in the postpartum period. The objective of this systematic review was to synthesize the currently available evidence of the impact of sleep, stress, and depression on postpartum weight retention.

Methods

Data sources and search strategy

Three electronic databases [PubMed, ISI Web of Science, PsycInfo] were searched for relevant articles in September 2013. A research librarian at the University of Massachusetts Medical School helped develop a search algorithm within the domains of sleep, stress, depression and postpartum weight retention (PPWR). Key words used in these searches included sleep, insomnia, apnea, stress, life events, distressed, depression, depressive symptoms, mood, postpartum, postnatal, women with young children, women with infants, post pregnancy, post childbirth, childbearing, weight retention, weight loss, weight gain, obese, obesity, body mass, body mass index (BMI), and adiposity. The full algorithm is detailed in Appendix A. Bibliographies of articles eligible for inclusion in the systematic review were also searched for additional references.

Inclusion and exclusion criteria

Publications included in this review had to: (1) be published between 1 January 1990 and 1 September 2013; (2) be published in English; (3) include as the study sample postpartum women who gave birth to their youngest child within the past 5 years; (4) assess any one of the following as the primary outcome: postpartum weight loss, PPWR, or transition to overweight or obesity through childbearing; and (5) examine at least one determinant of interest: sleep, stress, and/or depression in the postpartum period.

Publications were not considered for review if they did not meet inclusion criteria or: (1) were review articles, commentaries, editorials, or expert opinions; (2) were case reports or case series; (3) did not examine the association between at least one of the determinant(s) of interest and PPWR; (4) included women with multiple gestations.

Review process and data extraction

One author (RSX) performed an initial review of the titles and abstracts of all articles and excluded articles that did not meet our eligibility criteria. Two authors (RSX, ARKD) reviewed the full-text articles of a 1% random sample of articles that were excluded at this stage (n = 32); and agreement was 100% that all these articles had been appropriately excluded from inclusion in this review. Full-text articles were retrieved and retained for data abstraction if none of the exclusion criteria were met. One author (RSX) abstracted data from all included studies using a standardized form. The form included information on study design (e.g., cross-sectional, prospective or retrospective cohort, case–control study), sample size, the country in which the study was conducted, characteristics of study participants (e.g., age, parity, race/ethnicity, and pre-pregnancy body mass index), length of study/follow-up, time points of assessment, measures of predictors of interest (e.g., self-reported or via in-person interview), measures of outcome (e.g., self-reported weight, weight abstracted from medical record, or measured weight), major findings, and covariates included in multivariable regression models if applicable. Abstraction also included when and how postpartum sleep, stress, depression, and weight were measured in each study. The author (RSX) also abstracted how sleep duration was measured, either by self-report in number of hours spent sleeping or by using a validated questionnaire, and the categorization of sleep duration and the reference group, if available. Measures of postpartum stress and depression, by self-report or validated questionnaire, were also abstracted. The primary study outcomes included total PPWR, substantial PPWR, or return to pre-pregnancy weight (i.e., PPWR of zero). PPWR was defined by subtracting pre-pregnancy weight from postpartum weight. The first author abstracted how PPWR was defined in each study. A second author (ARKD) then independently reviewed all included studies and confirmed data presented in the tables.

Quality rating

We used a modification of the Downs and Black checklist to assess the methodological quality of each study, which has been used in a previous review [26]. The Downs and Black checklist was developed to assess the quality of both nonrandomized and randomized studies [27], containing 27 items with a maximum score of 32. We removed 8 items assessing randomization techniques that were not relevant to the objective of this review. The item on statistical power was dichotomized into whether or not the study reported a priori power analysis, with a score of 1. Our modified checklist consisted of 19 items with a maximum score of 20, assessing appropriate reporting of study objectives, methods and results, external and internal validity, and power analysis, where higher score indicates better study methodological quality. Two authors (RSX and ARKD) independently rated the quality of each study. We reported the observed proportion of agreement between the two raters [28]. We also calculated the intra-class correlation coefficient (ICC), a measure of inter-rater reliability and agreement for the quality rating total scores. An ICC >0.75 indicates almost excellent inter-rater reliability, ICC = 0.40–0.75 indicates fair to good agreement, and ICC < 0.40 indicates poor agreement [29]. Any discrepancies in quality ratings between the two reviewers were resolved through discussion.

Results

Study selection

The literature search yielded 5586 articles, from which 1630 duplicates were removed, leaving 3956 articles for review (Fig. 1). Of these, 3299 were excluded on the basis of title reviews and 595 based on reviews of the abstract. Of the 62 full-text articles reviewed, 12 met the inclusion criteria [30–41]. One additional publication [42] was identified from a search of bibliographies, for a total of 13 publications included in this review. The most common reasons for excluding publications after full-text review included no assessment of PPWR as the outcome variable (n = 28), no assessment of postpartum sleep, stress, or depression as the predictor variable (n = 17), or no associations examined between predictor variable(s) and PPWR (n = 5). This review includes 13 articles, which report on 9 study samples.

Study characteristics

The characteristics of studies are included in Table 1. Included studies were published between 1996 and 2013. The majority of studies recruited participants from hospitals [31,32,35,38,39,42], community newspaper birth announcements [40,41], or randomly selected participants from a registry of pregnant women [30,37]. Eleven studies were prospective cohort studies and two were cross-sectional studies [42,43]. Seven of the 11 prospective studies recruited women during pregnancy with average gestational ages from 20 weeks to 40 weeks and followed them for up to 12 months [30,32,35,38], 18 months [37], and 3 years postpartum [39]. The other four prospective studies recruited women within 3 months [31] and 6 months [33,34,40] postpartum and followed them up to 14 months, 18 months, and 2.5 years postpartum, respectively. Two cross-sectional studies recruited women at an average of 4.6 months [43] and 6 months postpartum [42]. Seven studies [32,35,36,38–41] were conducted in the United States, and six international studies were conducted in the Netherlands [30], Belgium [31], United Kingdom [33,34], Denmark [37], and Taiwan [42].

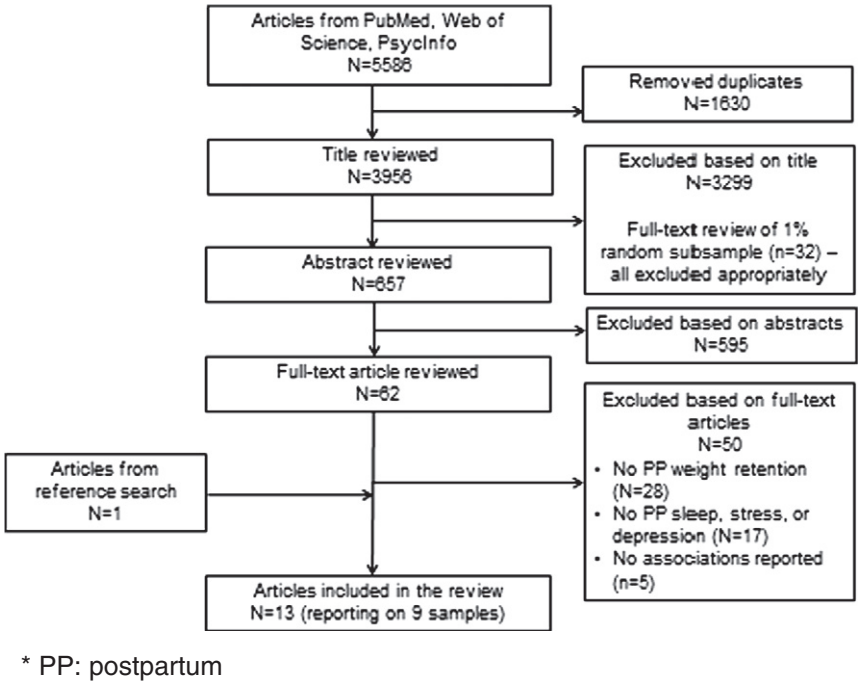

Fig. 1. Article selection process.

Analytic sample sizes ranged from 74 to 37,127 participants. Six studies [30,31,33,34,40,41] had 200 or fewer participants. Mean sample ages ranged from 26 [40] to 38 [39] years. The proportion of first-time mothers ranged from 30% [39] to 49% [30]. Five U.S. studies [32,35,38,39,43] reported the proportion of the sample that was non-Hispanic Whites, which ranged from 74% [39] to 98% [40]. Pre-pregnancy weights were either self-reported [30–32,36–41] or measured during the first trimester to provide an estimate of pre-pregnancy weight [33,34,42]. Postpartum weights were either self-reported [30,32,35–37,40,41] or directly measured [33,34,37–39,42].

Quality ratings

Raters agreed on 89% of all 19 quality rating items across the 13 included studies (range: 69–100%). The differences of total quality rating scores between two raters ranged from −2 to 2, with an average of 0. The agreement on total quality rating scores was excellent, with an ICC of 0.81 (95%CI: 0.50–0.93). After resolving discrepancies, total quality rating scores ranged from 12 to 18 with an average score of 15.6 (SD = 1.9) out of a possible score of 20, indicating good to high study quality.

Postpartum sleep duration

Four studies reported the association between sleep duration and PPWR (Table 2). Postpartum sleep duration was self-reported as the number of hours spent sleeping in the 24-hour period in the past week [30] or in the past month [32,38,39]. One study reported the inverse association between the number of hours spent in sleep at 6 months postpartum and total PPWR at 12 months postpartum [30]. Another study showed a positive association between short sleep duration, which was defined as less than 5 hours of sleep and total PPWR at 3 years postpartum [39]. Three studies [30,32,38] found mixed results in the association between postpartum sleep duration and substantial PPWR. Less than 5 hours of sleep at 3 months and 6 months postpartum were associated with a two-fold [38] and three-fold [32] risk of substantial PPWR at 12 months postpartum, respectively; however, the continuous number of hours spent in sleep was not associated with substantial PPWR at 12 months postpartum [30]. Decrease in sleep duration from 6 months to 12 months postpartum was associated with a two-fold increased risk of substantial PPWR at 12 months postpartum [32].

Postpartum stress

Four studies, from three study populations, reported the unadjusted associations between postpartum stress and PPWR (Table 3). One study [40] found a non-significant association between postpartum stress and PPWR after use of a multivariable regression model, but the specific findings were not reported. Postpartum stress was assessed using different instruments, including the Parenting Stress Scale [33,34], Perceived Stress Scale [40], and the Stress Scale from Psychosocial Profile [41]. Stress present at 6 months postpartum was not associated with total PPWR at 18 months postpartum [40], or PPWR over 0.4 kg at 2.5 years postpartum [33,34]. At 12 months postpartum, women's experiences of life-event stress were also not associated with total PPWR [41].

Postpartum depression

Eight studies reported the association between postpartum depression and PPWR (Table 4). Postpartum depression was measured using the Edinburgh Postnatal Depression Scale (EPDS) [31,33–36], Chinese version of the Beck Depression Inventory [42], Center for Epidemiologic Studies—Depression Scale (CES-D) [41], and Symptoms Checklist-92 [37]. Three studies reported the non-significant bivariate association between postpartum depression at 6 months postpartum and PPWR over 5 kg at 12 months postpartum [36], and PPWR over 0.4 kg at 2.6 years postpartum [33,34], respectively; while two studies reported a significant association [31,41]. Compared to women who had no depression at both pregnancy and postpartum period, those with depression only at 6 months postpartum period had an increased risk of PPWR over 5 kg at 12 months postpartum [35,37]. However, studies found conflicting results for women who had depression at both pregnancy and postpartum period. Depression at both periods did not increase women's risk of substantial PPWR over 5 kg at 12 months postpartum, where depression was assessed using EPDS; [35] however, it did increase women's risk of substantial PPWR at 12 months when questions for anxiety and depression were combined into a single scale [37].

Discussion

This review synthesized the findings of currently available studies that have examined the impact of postpartum sleep duration, stress, and depression on PPWR. Short sleep duration was associated with greater postpartum weight retention. Specifically, women with less than 5 hours of sleep at 6 months postpartum had a two- to three-fold risk of retaining more than 5 kg of weight at one to three years postpartum. Postpartum stress was not associated with PPWR, while the association between postpartum depression and PPWR was mixed. Women with depression only in the postpartum period had a higher risk of retaining pregnancy-related weight for over 5 kg, compared to those without depression both during pregnancy and postpartum.

Our findings among postpartum women were comparable to the findings in the general adult population. A recent systematic review [15] of sleep duration and subsequent weight gain found mixed associations between sleep duration and subsequent weight gain. Eight of 13 studies in adults found positive associations between short sleep duration and subsequent weight gain, while another five found non-significant associations. Another recent review of depression and obesity found less consistent evidence that depression leads to obesity [44]. Childbearing age is an important life stage for women that may result

Table 1
Study characteristics

First author, year	Study design, country	N	Sample characteristics	Predictors			Weight measures		Quality rating
				Sleep	Stress	Depression	Pre-pregnancy	PP	
Althuizen, 2011 [30]	Prospective cohort, Netherlands	118	Age: 31.6 (SD = 4.3) Primiparous: 49% Race/ethnicity: 93% European pre-pregnancy BMI: 24.3 (SD = 3.7)	X			Self-reported	Self-reported	13
Biesmans, 2013 [31]	Prospective cohort, Belgium	75	Age: 30.1 (SD = 4.3) Primiparous: N/A Race/ethnicity: 93.3% Belgian nationality pre-pregnancy BMI: N/A			X	Self-reported	Self-reported and measured	14
Gunderson, 2008 [32]	Prospective cohort, US	940	Age: 33 (SD = 4.7) Primiparous: 46.7%[a] Race/ethnicity: white (78%) Pre-pregnancy BMI: 24.3 (SD = 4.7)	X		X	Self-reported	Self-reported	18
Harris 1999 [34]	Prospective cohort, UK	74	Age: 33.5 (SE = 0.6) Primiparous: 37.8% Race/ethnicity: N/A Pre-pregnancy BMI: N/A		X	X	Measured at first trimester	Measured	15
Harris 1999 [33]	Prospective cohort, UK	74	Age: 33.5 (SE = 0.6) Primiparous: 37.8% Race/ethnicity: N/A Pre-pregnancy BMI: N/A		X	X	Measured at first trimester	Measured	17
Herring, 2008 [35]	Prospective cohort US	850	Age: 33.0 (SD = 4.7) Primiparous: 48% Race/ethnicity: 79% white[a] Pre-pregnancy BMI: 24.2 (SD = 4.7)	X		X	Self-reported	Self-reported	17
Huang, 2010 [42]	Cross-sectional Taiwan	602	Age: 30.2 (SD = 4.4) Primiparous: 44.2% Race: Asian Pre-pregnancy BMI: 21.5 (SD = 3.3)			X	Measured at first trimester and abstracted from medical record	Measured	16
Oken, 2008 [36]	Prospective cohort, US	902	Age: 33.0 (SD = 4.7) Primiparous: 47.5% Race: 79% white Pre-pregnancy BMI: 24.3 (SD = 4.8)			X	Self-reported	Self-reported	17
Pedersen, 2011 [31]	Prospective cohort, Denmark	37127	Age: 25–34 (76.9%) Primiparous: 40.4% Race: N/A Pre-pregnancy BMI: 27.1% OW/OB			X	Self-reported	Self-reported	18
Siega-Riz, 2010 [38]	Prospective cohort study, US	550	Age: 31.0 (SD = 5.5) Primiparous: 46% Race: 76.4% non-Hispanic white Pre-pregnancy BMI: 33% OW/OB	X		X	Self-reported	Measured	17
Taveras, 2011 [39]	Prospective cohort, US	586	Age: 37.7 (SD = 5.0) at 3 Y PP Primiparous: 30% Race/ethnicity: 74% white Pre-pregnancy BMI: 24.8 (SD = 5.2)	X		X	Self-reported	Measured	15
Walker, 1996 [34]	Prospective cohort, US	88 (6 M PP) 75 (18 M PP)	Age: 26.4 (SD N/A) Primiparous: 41% Race/ethnicity: 98% white Pre-pregnancy BMI: 14.8% OW/OB		X		Self-reported	Self-reported	12
Walker,1997 [35]	Cross-sectional, US	149	Age: 30.2 (SD = 5.5) Primiparous: N/A Race/ethnicity: 77% white Pre-pregnancy BMI: N/A		X	X	Self-reported	Self-reported	14

M: months; BMI: body mass index; N/A: not available; PP: postpartum; OW: overweight; OB: obese. SD: standard deviation; SE: standard error.
[a] Calculated from numbers in the Tables.

in substantial weight retention and lead to the development of obesity [45]. However, only a small number of studies have examined women's psychosocial experiences in relation to weight loss during the postpartum period. Future studies are needed to examine the impact of women's psychosocial experiences on PPWR, and the future development of obesity.

Methodological issues in included studies

This review revealed a number of findings regarding methodology. First, we found that most studies used self-reported pre-pregnancy weight and self-reported postpartum weight, rather than weights measured by research staff. This is a limitation in the field, as self-reported weight is well recognized to be an underestimation of actual weight in the general population [46]. Among women of childbearing age, self-reported weight was, on average, 1.5 kg lighter than their measured weights in previous research [47]. Three studies included in this review used weight measured in the first trimester to estimate the pre-pregnancy weight [33,34,42]. As reported in a prior study, self-reported weight was on average 1.8 kg lighter than weight measured at initiation of prenatal care [48]. Underestimation of pre-pregnancy weight will result in the overestimation of PPWR. While measuring pre-pregnancy weight is often not possible in the clinical setting, researchers should measure a woman's weight in the postpartum period to derive a better and more accurate measurement of PPWR.

Table 2
Postpartum sleep duration and PPWR

First author, year	Sleep duration	Primary outcome	Main findings
Althuizen, 2011 [30]	Self-reported, 6 W PP 6 M PP 12 M PP	Total PPWR 12 M PP SPPWR (PPWR ≥ 5 kg) 12 M PP	Unadjusted: not reported Adjusted: Sleep (hours/day) with total PPWR: b = −0.53, 95%CI: −1.08, −0.02 Model adjusted for social comparison for PA, energy intake, total GWG, and pre-pregnancy BMI Sleep (hours/day) with SPPWR: non-significant finding (data not shown)
Gunderson, 2008 [32]	Self-reported, 6 M PP 12 M PP	SPPWR (PPWR ≥ 5 kg) 12 M PP	5 h vs. 7 h of sleep at 6 M PP with SPPWR: Unadjusted: OR = 3.08, 95%CI: 1.76–5.38 Adjusted: OR = 3.13, 95%CI: 1.42–6.94 Model adjusted for sociodemographics, parity, pre-pregnancy BMI, GWG, PP behaviors, and change in sleep duration from 6 M to 12 M PP Decrease in sleep duration vs. no change from 6 M PP to 12 M PP with SPPWR Unadjusted: OR = 1.94, 95%CI: 1.19-3.17 Adjusted: OR = 2.05, 95%CI: 1.11-3.78 Model adjusted for sociodemographics, parity, pre-pregnancy BMI, GWG, PP behaviors, and change in sleep duration from 6 M to 12 M PP
Siega-Riz, 2010 [38]	Self-reported, 3 M PP	SPPWR (PPWR > =10 lbs, 4.5 kg) 3 M PP 12 M PP	≤5 h vs. 8+ h of sleep with SPPWR at 3 M PP: Unadjusted: not reported Adjusted: OR = 1.9, 95%CI: 1.5–2.4 Model adjusted for pre-pregnancy BMI, GWG, income, delivery mode, and depression ≤5 h vs. 8+ h of sleep with SPPWR at 12 PP: Unadjusted: Not reported Adjusted: Non-significant (data not shown)
Taveras 2011 [39]	Self-reported, 6 M PP 12 M PP	Total PPWR 3 Y PP	≤5 h vs. >5 h of sleep with total PPWR Unadjusted: b = 1.27, 95%CI: 0.08–2.61 Adjusted: b = 1.44, 95%CI: 0.02–2.86 Model adjusted for maternal age, race/ethnicity, education, parity, pre-pregnancy BMI, excessive GWG, and PP behaviors

* W: week; M: month; Y: year; PP: postpartum; PPWR: postpartum weight retention; SPPWR: substantial postpartum weight retention; GWG: gestational weight gain; BMI: body mass index; PA: physical activity; ED: eating disorder.

Second, postpartum sleep duration was self-reported in the form of number of hours spent in sleeping. Many postpartum women experience frequent nocturnal awakening that results in fragmented sleep or sleep disturbances that reduce sleep quality [9]. Recent research has discovered that mothers' total sleep time is preserved, but their sleep patterns are highly fragmented [49]. Although sleep pattern and quality were often measured among postpartum women in relation to their daily activities, depressive symptoms, and other health conditions [9,50], our review did not find any studies examining women's sleep pattern and quality during the postpartum period and its relationship to PPWR. We suggest that future studies examine sleep quality and particular patterns of disordered sleep among postpartum women and assess its relationship to PPWR.

Third, seven studies adjusted for a wide range of potentially confounding variables in estimating the association between postpartum psychosocial experiences and PPWR. Most studies included pre-pregnancy weight status and total or excessive gestational weight gain in their multivariable model, which were independently associated with a twofold to threefold risk of PPWR [45]. The lack of consistency in covariate selection is a limitation in the literature that hinders its systematic review. Considering the significant association between diet, physical activity, and weight gain, we suggest that future studies consistently adjust for postpartum physical activity, diet, pre-pregnancy weight status, gestational weight gain, and demographics in their multivariable regression models.

Fourth, four studies reported a non-significant association between postpartum stress and weight retention. The postpartum period is a potentially stressful transition period during which women face new tasks of motherhood and changes in their bodies [51]. Measures of stress used in the studies reviewed may not have captured aspects of stress particular to the postpartum period, which may bias the results towards the null hypothesis, even if there is a true association between postpartum stress and weight retention. All four studies that examined the association between postpartum stress and weight retention were published before 2000, and stressors faced recently by postpartum women may have changed over the past 15 years. More contemporary data are needed to examine the influence of stress on weight retention in the postpartum period.

Table 3
Postpartum stress and PPWR

First author, year	Stress	Primary outcome	Main findings
Harris, 1999 [34]	Parenting Stress Index 2.5 Y PP	SPPWR (PPWR > 0.4 kg) 2.5 Y PP	Unadjusted average Parenting Stress Index score by SPPWR No SPPWR: 221.8 (SD = 5.9) SPPWR: 223.2 (SD = 6.5); p value: not significant (data not shown) Adjusted: not reported
Harris, 1999 [33]	Parenting Stress Index 2.5 Y PP	PPWR 2.5 Y PP	Unadjusted Spearman correlation: r = 0.09; p = 0.43 Adjusted: not reported
Walker, 1996 [40]	Perceived Stress Scale 6 M PP	PPWR 6 M PP 18 M PP	Unadjusted: not significant (data not shown) Adjusted: not significant (data not shown) Model adjusted for race and GWG
Walker, 1997 [41]	The Stress Scale from Psychosocial Profile 12 M PP	PPWR 12 M PP	Unadjusted Spearman correlation: r = 0.07; p value: not significant (data not shown) Adjusted: not reported

M: month; PP: postpartum; PPWR: postpartum weight retention; SPPWR: substantial postpartum weight retention; GWG: gestational weight gain.

Table 4
Postpartum depression and PPWR

First author, year	Depression	Primary outcome	Main findings
Huang, 2010	BDI Chinese 6 M PP	Total PPWR 6 M PP	Unadjusted: not reported Adjusted: BDI with total PPWR among pre-pregnancy NW women: b = -0.10, p < 0.01 Model adjusted for body image, GWG, external health control, and parity of 1 BDI with total PPWR among other women: not significant (data not shown)
Herring, 2008 [35]	EPDS 6 M PP	SPPWR (PPWR > =5 kg) 12 M PP	Both pregnancy and PP depression vs. neither depression with SPPWR: Unadjusted: OR = 1.28, 95%CI: 0.37–4.41 Adjusted: OR = 0.68, 95%CI: 0.16–2.99 Model adjusted for pre-pregnancy BMI, GWG, parity, and maternal sociodemographics Only PP depression vs. neither depression with SPPWR: Unadjusted: OR = 3.00, 95%CI: 1.40–6.41 Adjusted: OR = 2.54, 95%CI: 1.06–6.09 Model adjusted for pre-pregnancy BMI, GWG, parity, and maternal sociodemographics Adjusted: OR = 2.38, 95%CI: 0.96–5.88 Model adjusted for pre-pregnancy BMI, GWG, parity, maternal sociodemographics, and PP behaviors
Biesmans, 2013 [31]	EPDS, 3 M PP	PPWR (Yes/no) 14 M PP	Unadjusted mean EPDS score by PPWR (yes/no): PPWR: 6.9 (SD = 4.9) No PPWR: 5.0 (SD = 3.1); p = 0.042 Adjusted: not reported
Oken, 2008 [36]	EPDS, 6 M PP	SPPWR (PPWR ≥ 5 kg) 12 M PP	Unadjusted percentage of women with an EPDS score >12 by SPPWR: SPPWR: 12% No SPPWR: 7%; p = 0.09 Adjusted: not reported
Pedersen, 2011 [37]	Symptoms Checklist-92 6 M PP	SPPWR (PPWR ≥ 5 kg) 6 M PP 18 M PP	Unadjusted: not reported Adjusted (data abstracted from figure): Both pregnancy and PP depression vs. neither depression with SPPWR at 6 M PP: OR = 1.4, 95%CI: 1.3–1.6 SPPWR at 18 M PP: OR = 1.5, 95%CI: 1.3–1.7 Model adjusted for age, parity, pre-pregnancy BMI, smoking, and exercise during pregnancy Only PP depression vs. neither depression with SPPWR at 6 M PP: OR = 1.1, 95%CI: 0.98–1.2 SPPWR at 18 M PP: OR = 1.3, 95%CI: 1.1–1.5 Model adjusted for age, parity, pre-pregnancy BMI, smoking, and exercise during pregnancy
Harris, 1999 [34]	EPDS 6 M PP	SPPWR (PPWR ≥ 0.4 kg) 2.6Y PP	Unadjusted mean EPDS score by SPPWR: SPPWR: 6.6 (SD = 0.9), No SPPWR: 5.0 (SD = 0.8); p value: not significant (data not shown) Adjusted: not reported
Harris, 1999 [33]	EPDS 6 M PP	PPWR 2.6Y PP	Unadjusted Spearman correlation: r = -0.05; p = 0.65 Adjusted: not reported
Walker, 1997 [41]	CES-D 12 M PP	PPWR 12 M PP	Unadjusted Spearman correlation: r = 0.20; p < 0.01 Adjusted: not reported

BDI: Beck Depression Inventory; M: month; PP: postpartum; PPWR: postpartum weight retention; NW: normal weight; GWG: gestational weight gain; SPPWR: substantial postpartum weight retention; Y: year; BMI: body mass index; preg: pregnancy; EPDS: Edinburgh Postpartum Depression Scale; CESD: Center for Epidemiologic Studies Depression Scale.

Fifth, sleep disruption is one manifestation of major depression in adult populations [52] and there is a strong bi-directional association between alterations of sleep and depression [53]. Women with new onset of postpartum depression had a 2.5 times increased odds of retaining over 5 kg of weight, compared to women without depression during pregnancy and postpartum period. However, after adjusting for postpartum behaviors, including sleep, there was no significant association between new onset of postpartum depression and PPWR [35]. Although a few studies included sleep duration and postpartum depression in their adjusted models, the combined effect of sleep duration and depression on PPWR could not be determined in this review. Meanwhile, three studies presented the non-significant bivariate association between postpartum stress and PPWR, and the non-significant bivariate association between postpartum depression and PPWR. As postpartum stress and depression were also highly correlated, we were not able to determine whether one predictor mediated the association between the other and PPWR. Considering the interrelationships between sleep duration, stress, and depression, future research is needed to examine their combined effect on PPWR.

Study strengths and limitations

This systematic review has several strengths. We reviewed multiple databases and used a systematic approach to identify published research from the clinical, psychological, and nursing literature. Two authors independently reviewed articles and rated study quality. This review extends the current literature on postpartum weight retention by examining the associations of sleep duration and depression with weight retention, and highlights the lack of literature on postpartum stress and weight retention and the need for future research in this area. This review also has several limitations. Two authors reviewed the full-text articles of a 1% random sample of articles excluded based on title alone; all articles were found to have been excluded appropriately, suggesting that our review process was unlikely to have omitted relevant articles from inclusion in this systematic review. We used a modified version of the Downs & Black checklist. While the original checklist demonstrated sufficient psychometric validity [27], this modified version has not been validated. However, this modified version has been used in previous research [26]. This review included only studies published in English, potentially omitting pertinent research published in other languages. Because of the sparse literature available, and the differing ascertainment methods and timing of measurement of sleep, stress, depression, and postpartum weight loss across studies, a quantitative meta-analysis could not be performed.

Conclusion

Validated measures of postpartum sleep patterns, ideally over varying periods, are needed in future research. Given the limited evidence about whether sleep, stress, and depression impact PPWR, we

suggest additional observational research to establish the role of these three factors in postpartum weight loss in order to better identify women at greatest risk for PPWR. Future postpartum weight loss intervention studies may be important to address these factors in the intervention content to better help postpartum women lose weight.

Competing interest statement

All authors have completed the Unified Competing Interest form at http://www.icmje.org/coi_disclosure.pdf and declare that 1) Dr. Pagoto is on the advisory board of Empower Fitness and had a contract with Sears FitStudio. 2) The other authors have no other potential conflicts of interest to report.

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RSX completed the abstraction of titles and abstracts. RSX and ARKD independently reviewed articles and rated study quality, and reviewed the full-text articles of a random 1% sample of articles excluded based on title. RSX and MEW drafted the manuscript. RSX, ARKD, RJG, SLP, SDP, and MEW helped interpret the results. ARKD, RJG, SLP, and SDP provided critical revision to the manuscript. All authors had read the article and approved the final version to be submitted.

Appendix A. Searching algorithm

[(Sleep OR insomnia OR snoring OR apnea) OR
(Stress OR distressed OR hassle OR stressful OR life events) OR
(Depression OR depress OR depressive OR antidepressant OR mood)]
AND
(Postpartum OR postpartum OR post pregnancy OR postnatal OR after pregnancy OR post childbirth OR after delivery OR after childbirth OR moms OR mothers OR women with young children OR women with infants)
AND
(Weight loss OR weight gain OR weight change OR weight retention OR body mass OR adiposity OR obesity OR overweight OR obese)

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